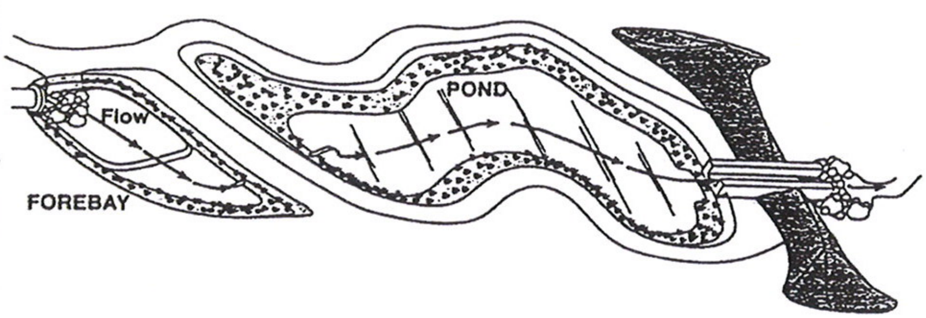
ACTIVITY: Wet Detention Ponds — WPTP-01



Targeted Constituents				
● Significant Benefit		◗ Partial Benefit		○ Low or Unknown Benefit
● Sediment	● Heavy Metals	● Floatable Materials	◗ Oxygen Demanding Substances	
◗ Nutrients	● Toxic Materials	◗ Oil & Grease	◗ Bacteria & Viruses	◗ Construction Wastes

Implementation Requirements			
● High	◗ Medium		○ Low
● Capital Costs	◗ O & M Costs	◗ Maintenance	○ Training

Description

A wet detention pond has a permanent water pool to treat incoming stormwater. A wet detention pond can be enhanced with a pretreatment sediment forebay, baffle box, or stormwater quality inlet. This management practice will provide a significant reduction in sediment, heavy metals, toxic materials, and floatable materials as well as partial reductions in the impacts due to nutrients, oxygen demanding substances, oil and grease, and bacteria and viruses.

Selection Criteria

- Need to achieve high level of particulate and some dissolved contaminant removal.
- Ideal for large, regional tributary areas.
- Multiple benefits of passive recreation (e.g., multi-purpose facilities, bird watching, wildlife habitat). See figure WPTP-01-9.

Design and Sizing Considerations

- These systems should be designed by a licensed professional civil engineer.
- Wet detention ponds should be designed as "off-line" structures to limit environmental impacts downstream when maintaining the facility. On-line facilities may be acceptable depending on specific site characteristics.
- The major features of a wet detention pond are shown in Figures WPTP-01-1 and WPTP-01-2. It is essentially a small lake with rooted wetland vegetation along the perimeter. The permanent pool of water (below the weir crest, culvert, or inlet) provides a quiescent volume for continued settling of particulate contaminants and uptake of dissolved contaminants by aquatic plants between storms. The wetland vegetation is present to improve the removal of dissolved contaminants and to reduce the formation of algal mats. The "live" pool provides flood control, erosion control, and additional treatment benefits.
- The permanent pool should have a hydraulic residence time of at least 2 to 4 weeks.

- The maximum depth of the permanent pool is generally less than 12 feet (3.7 m), although greater depths are possible with artificial mixing or aerators at maximum depth. The objective is to avoid thermal stratification that could result in odor problems associated with anaerobic conditions. Gentle artificial mixing may be needed in small ponds because they are effectively sheltered from the wind.

- In industrial applications ground water or treated process water may have to be pumped into the facility to maintain the water level. The permanent pond could be allowed to dry during maintenance periods.

- The outlet of the facility should be restricted so as to detain a treatment design storm in a "live" pool on top of the permanent pool for 24 to 60 hours. The effect of restricting the outflow is to reduce the overflow rate during the storm reducing downstream erosion, flood control and slightly increasing the capture of settleable solids.

- Water quality detention ponds should be sized to collect the first flush of stormwater runoff. For this area, the first flush is generally the first 0.5 to 1.1 inches of runoff over the tributary area.

- About 10 to 25% of the surface area determined in the above procedure should be devoted to the forebay. The forebay can be distinguished from the remainder of the pond by one of several means: a lateral sill with rooted wetland vegetation, two ponds in series, differential pool depth, rock-filled gabions or retaining wall, or a horizontal rock filter placed laterally across the pond. A baffle box or water quality inlet(s) can be used in lieu of a forebay.

<u>Sizing the "Live" Pool</u>

The following method should be used to calculate the "live" pool volume.

- The recommended performance goal is at least 85 to 95% capture of the annual average runoff volume. The live pool may be calculated using long-term hourly hydrologic data and runoff capture simulation curves that consider a runoff coefficient for land use to determine a unit basin storage volume (v). This has been analyzed for the Nashville area and is presented in Figure WPTP-01-3.

$$V_L = (A_T * v)/12$$

where: V_L = pond volume (acre-feet);
A_T = Total Tributary Area (acres); and
v = unit basin storage volume (inches) – taken from Figure WPTP-01-3 (0.5 to 1.1 inches)

- This live pool volume will add to the overall volume and will benefit the downstream waterways by reducing erosive velocities, providing flood control and an incremental increase in treatment.

<u>Sizing the Permanent Pool</u>

- Two methods are available for the sizing of the permanent pool portion of the wet detention ponds. One proposed on the removal of phosphorus (Florida, 1988; Maryland, 1986) It provides a detention time of 14 days based on the wettest month to allow sufficient time for the uptake of dissolved phosphorus by algae and the settling of fine solids where the particulate phosphorus tends to be concentrated. The following two methods should be used to calculate the permanent pool volume. The most conservative (largest volume) should be selected.

Size the permanent pool portion of the wet pond using the wettest 14-day period using the following formula:

$$V_p = (CA_TR)/12$$

Where: V_p = permanent pool volume (acre-ft)
C = contributing area weighted average runoff coefficient
A_T = Total Tributary Area (acres)
R = 14 day wet season rainfall (inches)
= 2.04 inches for the Nashville area

The second method predicts the removal of particulate contaminants only (USEPA, 1986). It relates the removal efficiency of suspended solids to pond volume. Using this method, the volume of the permanent pool may be calculated as follows:

$$V_P = V_{B/R}S_dA_i43560/12 = 14520S_dA_i$$

where: V_P = permanent pool volume (ft^3)
$V_{B/R}$ = Ratio of Basin to Runoff Volume (Figure WPTP-01-7)
(a value of at least 4.0 should be used)
S_d = mean storm depth (inches)
A_i = impervious acres in the tributary watershed

For A_i directly connected impervious acres may be used because it more correctly represents the area being treated. Although impervious area and directly connected impervious area are not the same, the substitution of directly connected impervious area for total impervious area is reasonable given the uncertainty of the methodology and expected pond performance.

- Wetland vegetation, occupying 25-50% of water surface area.
- Side slopes should be 6:1 (H:V) or flatter to provide a littoral shelf and safety bench from the side of the facility out to a point 2 to 3 feet (0.61 to 0.91 m) below the permanent pool elevation. Side slopes above the littoral zone should be no steeper than 4:1 (H:V). Side slopes below the littoral zone can be 2:1 (H:V) to maximize permanent pool volumes where needed. A short (1.0 foot (0.3 m)) drop-off can be constructed at the edge of the pond to control the potential breeding of mosquitoes.
- Skimmers – Facilities that receive stormwater from contributing areas with greater than 50 percent impervious surface or that are a potential source of oil and grease contamination must include a baffle, skimmer, and grease trap to prevent these

substances from being discharged from the facility.

- Bedrock must be considered in the Nashville area because excavation may be required for grading for a permanent pool. The permanent pool may be excavated into bedrock for a wet or dry detention pond, but the cost may be prohibitive. Furthermore, if there is highly fractured bedrock or karst topography, then the modification of a detention pond should be carefully considered because it may not hold water and the additional water flow and/or weight could intensify karst activity.

- The interaction with other utilities must be considered as it may not be practical to develop a permanent pool in an area that is needed by another utility. Furthermore, the cost of designing around utilities or utility relocation must be considered.

- Access must be considered to account for maintenance crews and public interaction. Maintenance crews must have access to the site for proper maintenance. Ponds that are not designed with access for maintenance crews often become more of a nuisance than a beneficial part of a stormwater management program. It may also be desirable to encourage or discourage access for the public. Public education and recreation may be facilitated by access to the pond, provided public safety is sufficiently addressed. In some cases including some source landuse conditions, however, it may be desirable to restrict public access such as in especially sensitive or dangerous areas.

- Design to minimize short-circuiting by including energy dissipaters on inlets, shape the pond with at least a 3:1 length to width ratio, and locate the inlets as far away from the outlet as possible. It should be noted that a length to width ratio of up to 7:1 is preferred. The inlet and outlet can be placed at the same end if baffling is installed to direct the water to the opposite end before returning to the outlet. If topography or aesthetics requires the pond to have an irregular shape, the pond area and volume should be increased to compensate for the dead spaces.

- Except for very small facilities, include a forebay, baffle box, or stormwater quality inlet to facilitate maintenance. However, note that a forebay will require less frequent maintenance.

- Use side slopes of at least 4:1 (H:V) or flatter unless vertical retaining walls are used.

- To maintain the wet pool to the maximum extent possible, excessive losses by infiltration through the bottom must be avoided. Depending on the soils, this can be accomplished by compaction, incorporating clay into the soil, or an artificial liner.

- With earthen walls, place an antiseep collar around the outlet pipe.

- The outlet should incorporate an antivortex device if the facility is large (a 100-year storm must safely pass through or around the device).

- The sides of an earthen wall should be vegetated to avoid erosion. Drought tolerant groundcover species should be used if irrigation can not occur during the summer.

- Ponds that serve smaller local site runoff do not offer as much recreational benefit as ponds serving larger regional runoff. Regional facilities can often be landscaped to offer recreational and aesthetic benefits. Jogging and walking trails, picnic areas, ball fields, and canoeing or boating are some of the typical uses. For example, portions of the facility used for flood control can be kept dry, except during floods, and can be used for exercise areas, soccer fields, or football fields. Wildlife benefits can also be provided in the form of islands or preservation zones, which allow a view of nature within the park schemes. Figure WPTP-01-9 is an example of a multi-use regional facility.

- The public's safety must be a foremost consideration. For the design of wet detention ponds, this usually takes place in the grading, fencing, landscaping, pipe cover, grating and signage. The most important design feature affecting public safety during a pond's operation is grading. The contours of the pond should be designed to eliminate "drop-offs". When possible, terraces or benches are used to transition into the permanent pool. Within the permanent pool, it is desirable to have a wet terrace 12 to 18 inches below the normal pool level. In some cases there is not sufficient room for grading of this type and the pond may require a perimeter fence.

<u>Outlet Design</u>

- Proper hydraulic design of the outlet is critical to achieving good performance of the detention basin. The two most common outlet problems that occur are: 1) the capacity of the outlet is too great resulting in partial filling of the basin and less than designed for drawdown time and 2) the outlet clogs because it is not adequately protected against trash and debris. To avoid these problems, two alternative outlet types are recommended for use: 1) V-notch weir, and 2) perforated riser. The V-notch weir will not clog as easily.

<u>Flow Control Using a "V" Notch Weir</u>

- The outlet control "V" notch weir should be sized using the following formula (Merritt et.al., 1996).

$$Q = C_1 H^{5/2} \tan\left(\frac{\theta}{2}\right)$$

Where

θ = notch angle
H = head or elevation of water over the weir, ft
C_1 = discharge coefficient (see Figure WPTP-01-8)

The notch angle should be 20° or more. If calculations show that a notch angle of less than 20° is appropriate, then the outlet should be designed as a uniform width notch. This will generally necessitate some sort of floatables control such as a skimmer on the outlet or trash rack on the inlet.

Flow Control Using a Single Orifice

- The outlet control orifice should be sized using the following equation (GKY, 1989).

$$a = \frac{2A(H-H_o)^{0.5}}{3600cT(2g)^{0.5}} = \frac{(7x10^{-5})A(H-H_o)^{0.5}}{cT} \quad (1)$$

where: A_o = area of orifice (ft^2)
A_p = average surface area of the pond (ft^2)
c = orifice coefficient
T = drawdown time of full pond (hrs.)
g = gravity (32.2 ft/sec^2)
H = elevation when the pond is full (ft)
H_f = final elevation when pond is empty (ft)

With a drawdown time of 40 hours the equation becomes:

$$A_o = \frac{(1.75x10^{-6})A_p(H-H_f)^{0.5}}{c} \quad (2)$$

Care must be taken in the selection of "c": 0.60 is most often recommended and used. However, based on actual tests GKY (1989) recommends the following:

c = 0.66 for thin materials, that is, the thickness is equal to or less than orifice diameter
c = 0.80 when the material is thicker than the orifice diameter

Drilling the orifice into an outlet structure that is made of concrete can result in considerable impact on the coefficient, as does the beveling of the edge.

- Additional steps may be necessary to be certain that the small storms, which represent the majority of pollution, are effectively treated. One approach would be to check the design analysis to determine if the facility takes 24 to 48 hours to drain when half full. If not, either modify the design to achieve this objective, or install a two orifice outlet. The lower outlet is sized to drain a half-full facility in 24 hours. The second orifice is placed at the mid-water elevation and is sized in combination with the lower orifice to drain the entire facility in 48 hours. Another approach is to install the outlet about one foot above the bottom of the pond (essentially enlarging the micropool area). This lower area will dry up between storms and will capture much of the volume of small storms and improving pollutant removal.

- To prevent clogging of an orifice and the bottom orifices of the riser pipe, wrap the bottom three rows of orifices with geotextile fabric and a cone of one to three inch rock.

TABLE 2A PERFORATED OUTLET RISER PIPE ORIFICES (Austin, 1988)

RISER PIPE DIAMETER	VERTICAL SPACING BETWEEN ROWS (center to center)	NUMBER OF PERFORATIONS	PERFORATION DIAMETER
6 in. (15.2 cm)	2.5 in. (6.4 cm)	9 per row	1 in. (2.54 cm)
8 in. (20.3 cm)	2.5 in. (6.4 cm)	12	1 in. (2.54 cm)
10 in. (25.4 cm)	2.5 in. (6.4 cm)	16	1 in. (2.54 cm)

Flow Control Using the Perforated Riser

For outlet control using the perforated riser as the outflow control, it is recommended that the procedure illustrated in WPTP-01-5 and 6. This design incorporates flow control for the small storms in the perforated riser but also provides an overflow outlet for large storms. If properly designed, the facility can be used for both water quality and drainage control by: 1) sizing the perforated riser as indicated for water quality control; 2) sizing the outlet pipe to control peak outflow rate from the 2-year storm; and 3) using a spillway in the pond berm to control the discharge from larger storms up to the 100-year storm.

- See the Stormwater Management Ordinance for additional information on the design of detention facilities.

Maintenance

- Remove floatables and sediment build-up.
- Correct erosion spots in banks.
- Check at least annually and after each extreme storm event. The facility should be cleaned of accumulated debris. The banks of surface ponds should be checked and areas of erosion repaired. Remove nuisance wetland species and take appropriate measures to control mosquitoes. Remove sediments if they are within 18 inches of an orifice plate.

Sediment Removal

- Primary functions of detention ponds are to collect sediments. The sediment accumulation rate is dependant on a number of factors including watershed size, facility sizing, construction upstream, industrial or commercial activities upstream, etc. The sediment contents should be identified before it is removed and disposed.

  Some sediment may contain contaminants of which the Tennessee Department of Environment and Conservation (TDEC) requires special disposal procedures. If there is any uncertainty about what the sediment contains or it is known to contain contaminants, then TDEC should be consulted and their disposal recommendations followed. The TDEC – Division of Water Pollution Control should be contacted at (615) 532-0625. Generally, special attention or sampling should be given to sediments accumulated in facilities serving industrial, manufacturing or heavy commercial sites, fueling centers or automotive maintenance areas, large parking areas, or other areas where pollutants (other than "clean" soil) are suspected to accumulate and be conveyed via storm runoff.

Some sediment collected may be innocuous (free of pollutants other than "clean" soil) and can be used as fill material, cover or land spreading. It is important that this material not be placed in a way that will promote or allow resuspension in storm runoff. The sediment should not be placed within the high water level area of the pond, other BMP, creek, waterway, buffer, runoff conveyance device, or other infrastructure. Some demolition or sanitary landfill operators will allow the sediment to be disposed at their facility for use as cover. This generally requires that the sediment be tested to ensure that it is innocuous.

- Solids should be removed when 10 to 15% of the storage capacity has been lost.
- The pond's success as a mechanism to benefit water quality is dependent on maintaining the permanent pool, skimmer devices, and inlet and outlet structures. This maintenance typically includes sediment, floatable, and debris removal from inlets, outlets and skimmers.
- Pond vegetation need to be trimmed or harvested as appropriate, grassy areas frequently mowed and repairs made to signage, walkways, picnic tables, or any other public recreation equipment.
- If both the operational and aesthetic characteristics of a wet pond are not maintained, then it will be viewed as an eyesore and negative environmental impact even if it is functioning properly.

Limitations

- Concern for mosquitoes and maintaining oxygen in ponds.
- Cannot be placed on steep unstable slopes or on shallow fractured bedrock.
- Infeasible in very dense urban areas.
- For larger detention facilities, the structural integrity of the impounding embankment should also be considered. The embankment should be protected against catastrophic dam failure. Pending volume and depth, pond designs may require approval from TVA, TDEC, or USACOE for various reasons including dam safety.
- May require permits from various regulatory agencies, e.g., TVA, TDEC, USACOE.

Additional Information

Wet detention ponds are of interest where the removal of the dissolved constituent fraction is of concern, particularly nutrients and metals. Dissolved contaminants are removed by a combination of processes: physical adsorption to bottom sediments and suspended fine sediments, natural chemical flocculation, and uptake by aquatic plants.

A "V" notch weir outlet structure as illustrated in Figure WPTP-01-4 is preferred.

Rooted vegetation around the pond perimeter serves several functions. It enhances the removal of dissolved pollutants; it may reduce the formation of floating algal mats; it reduces the risk of people falling into the deeper areas of the pond; and, it provides some habitat for insects, aquatic life, and wetland wildlife. The "shelf" for the vegetation should be about 10 feet (3 m) wide with a water depth of 1 to 2 feet (0.3 to 0.61 m). The total area of the "shelf" should be at least 25% of the water surface area. Vegetation near the exit will assist settling of solids. An alternative is a rock filter which is used in many wastewater oxidation ponds where loss of algae in the effluent is a common problem during the growth season.

If mosquitoes are of particular concern, it would be advisable to inhibit the growth of emergent wetland vegetation around the perimeter by installing a 12" shelf transition into bed slopes that will minimize the amount of pond area that has a depth less than 12". Gambusia (mosquito fish) can also be placed in larger ponds but the water level must be maintained to insure their survival during the dry season.

If placement of wetland vegetation along the perimeter is not feasible, consider the use of devices that retain non-rooted wetland species. Non-rooted vegetation is more effective than rooted vegetation in removing dissolved nutrients and metals. The vegetation grows within the device which is periodically removed and cleaned thereby removing the contaminants from the facility.

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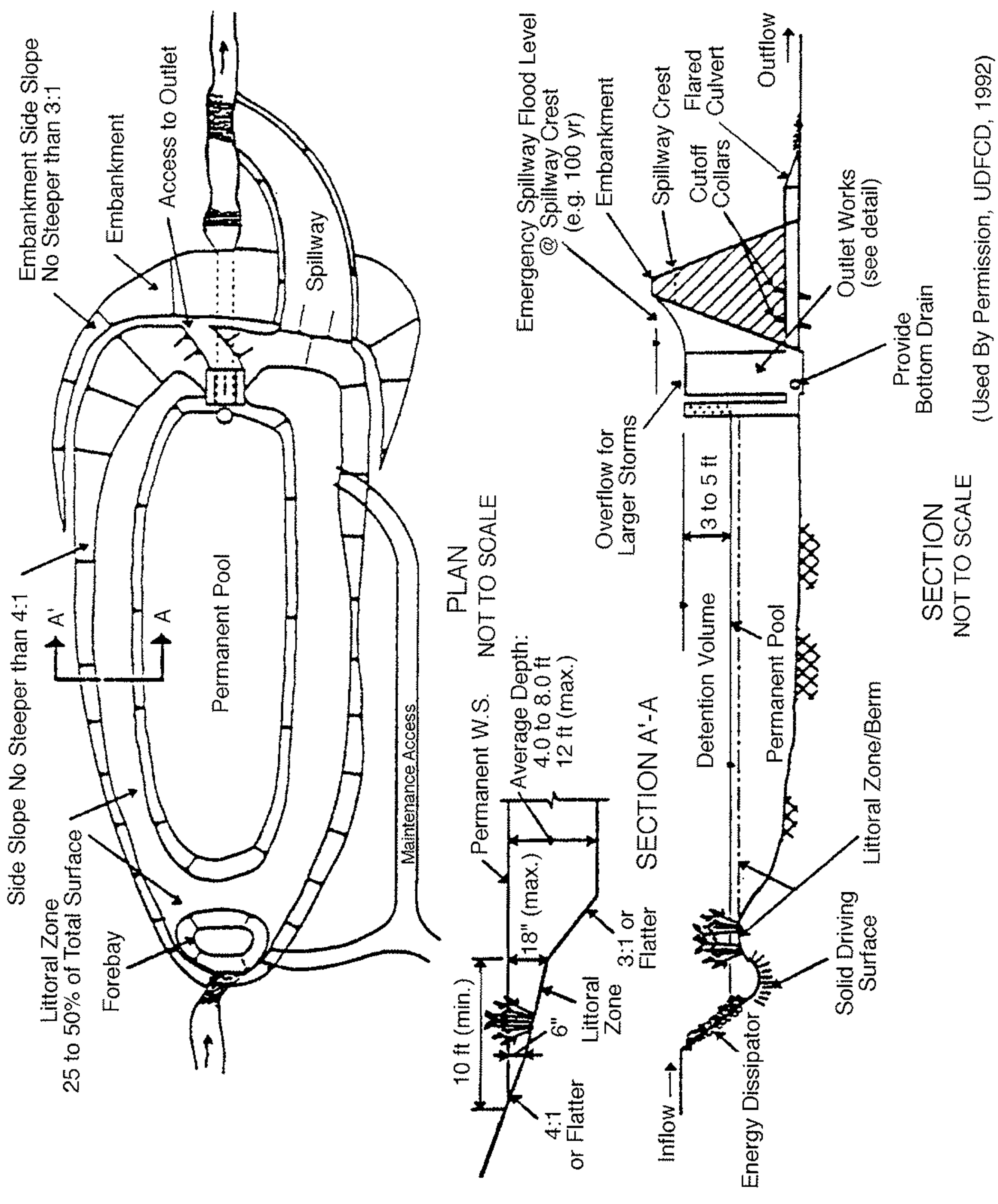


Figure WPTP-01-1
Wet Pond Layout

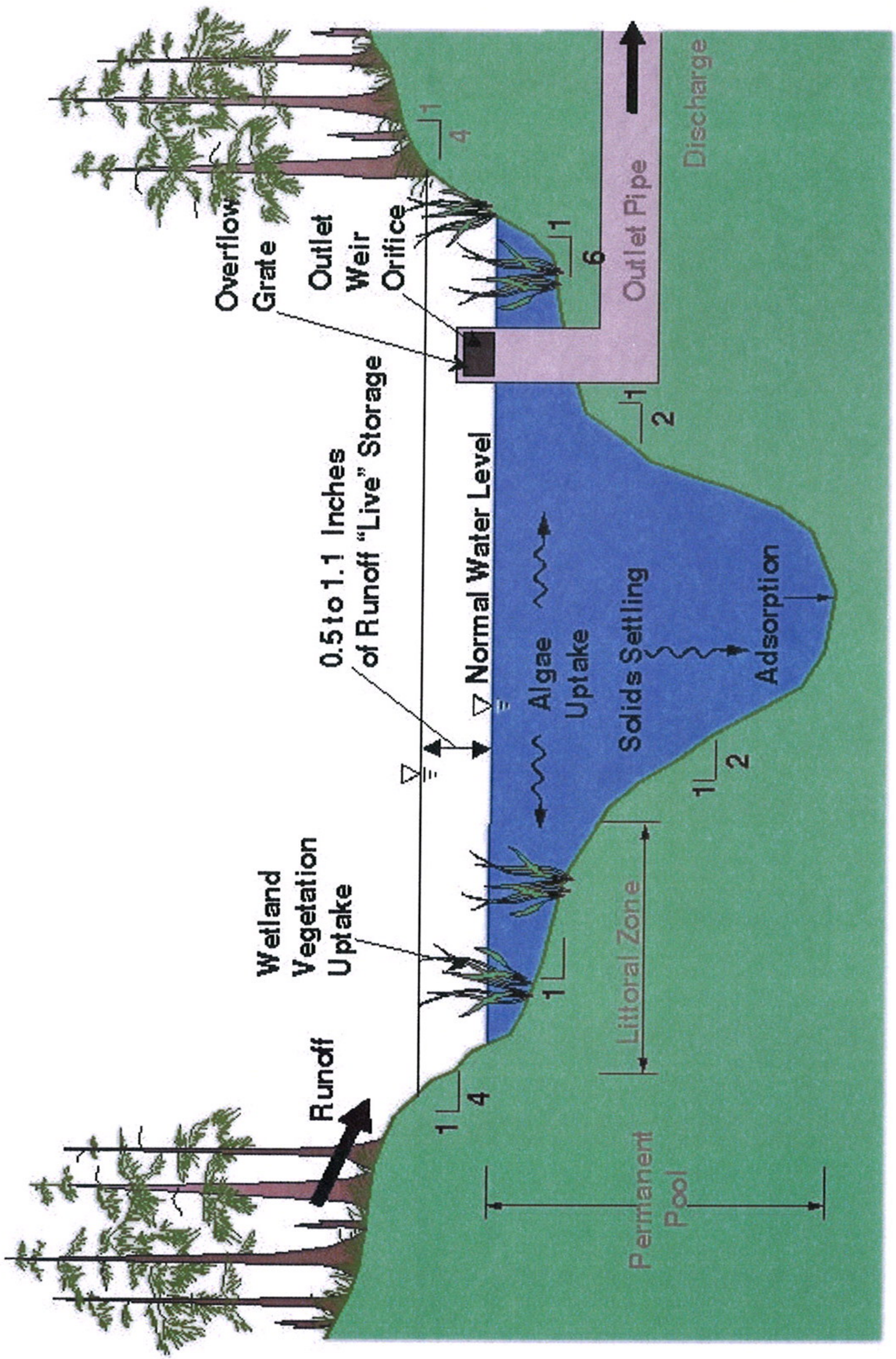


Figure WPTP-01-2
Wet Pond Layout

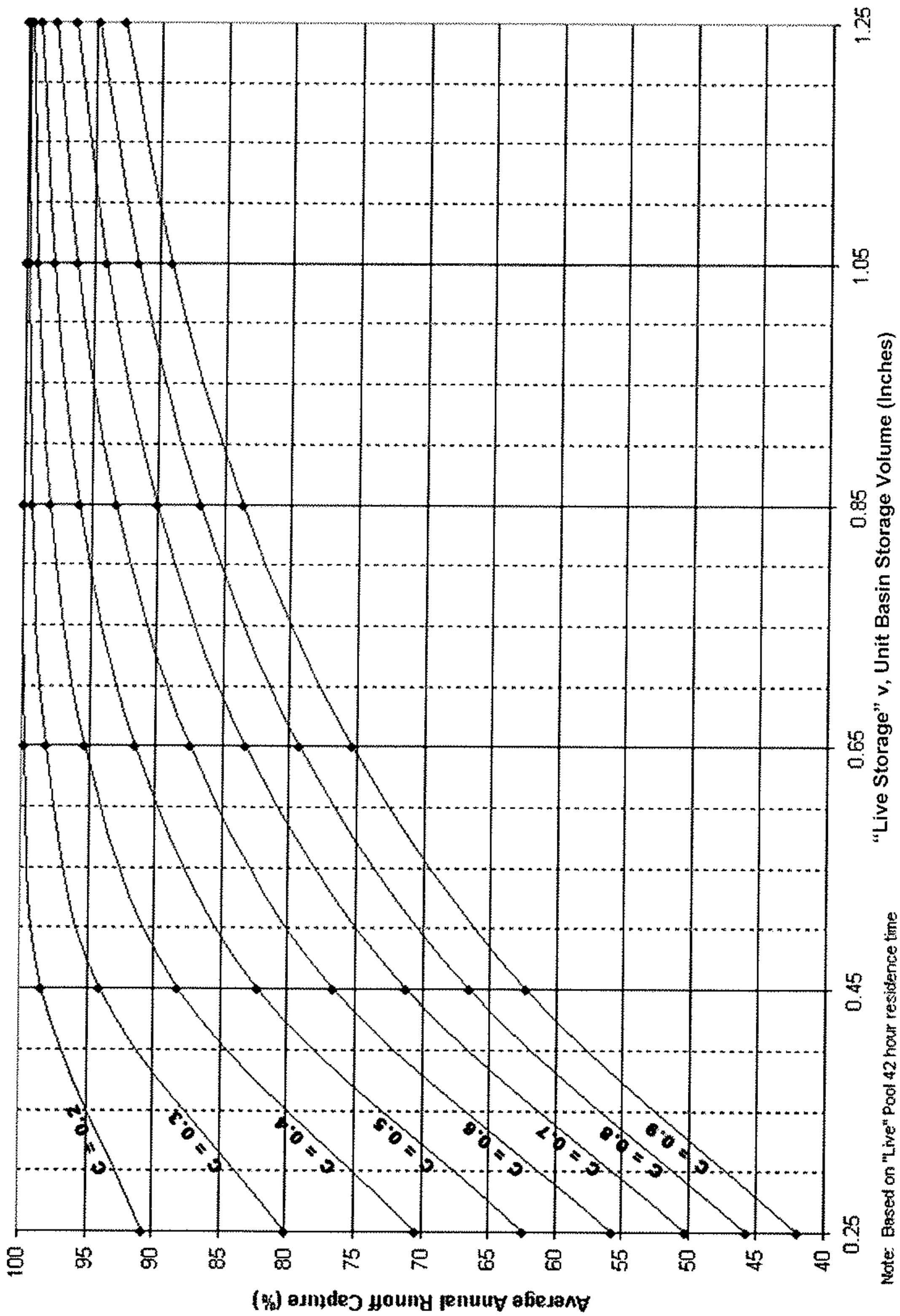
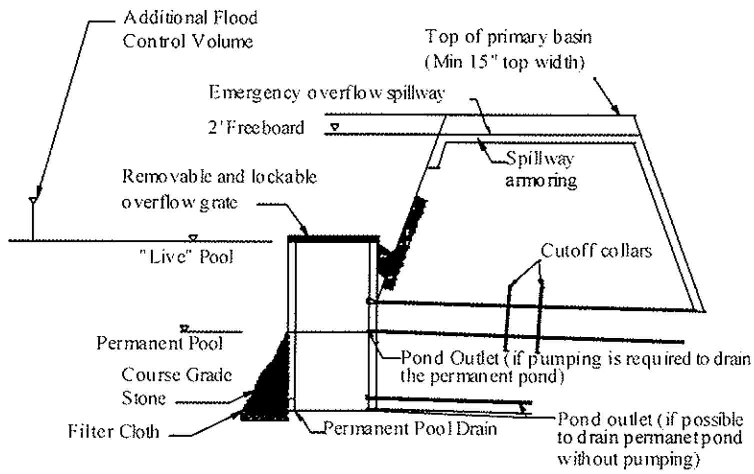
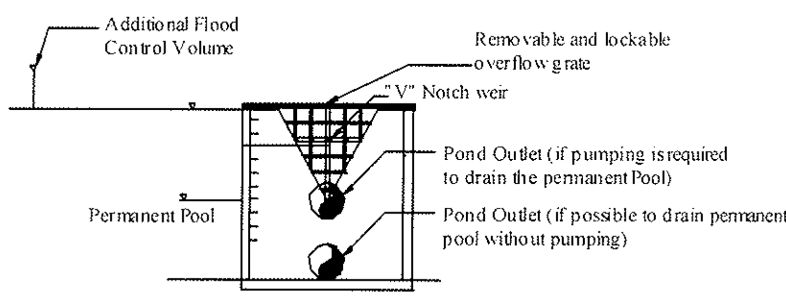


Figure WPTP-01-3
Wet Detention Average Annual Runoff Volume Capture



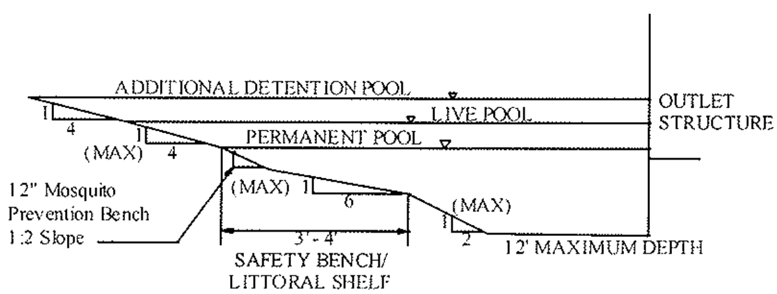
SECTION OUTLET STRUCTURE

NTS



PROFILE OUTLET STRUCTURE

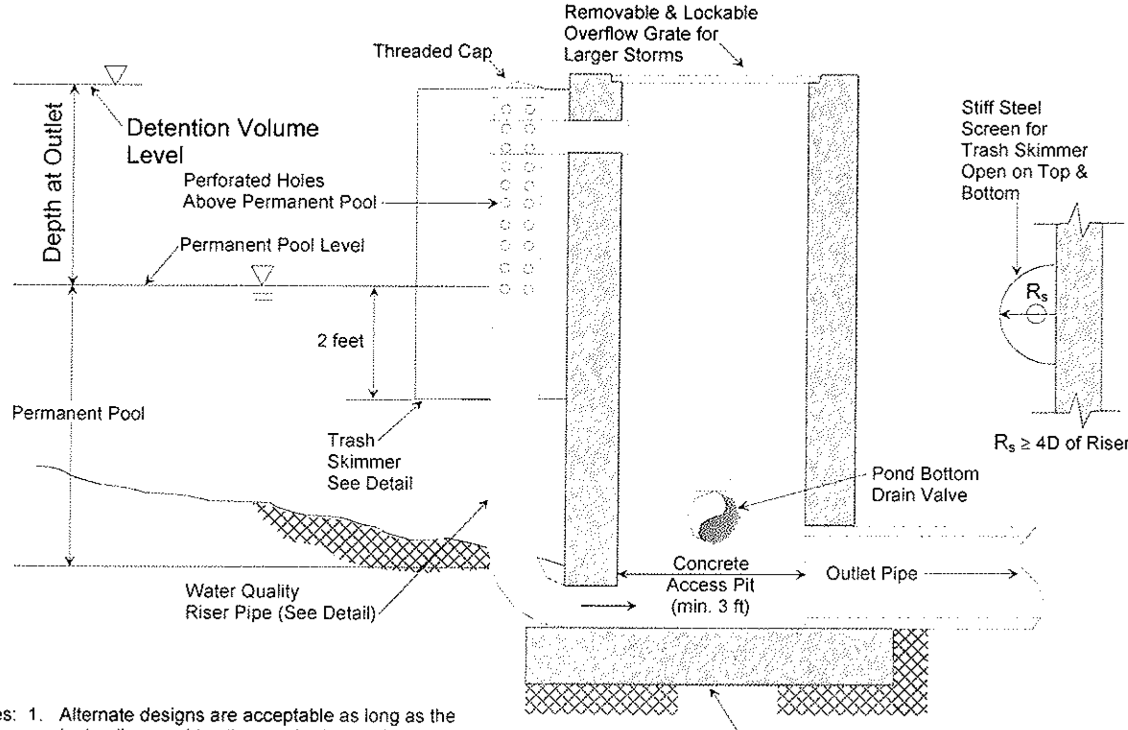
NTS



POND GRADING

NTS

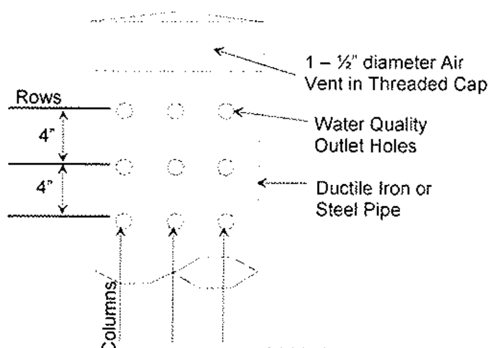
Figure WPTP-01-4
"V" Notch Weir Outlet Structure



Notes:
1. Alternate designs are acceptable as long as the hydraulics provides the required emptying times.
2. Use trash skimmer screens of stiff green steel material to protect perforated riser. Must extend from the top of the riser to 2 ft. below the permanent pool level.

OUTLET WORKS
NOT TO SCALE

Notes:
1. Minimum number of holes = 8
2. Minimum hole diameter = 1/8" Dia.



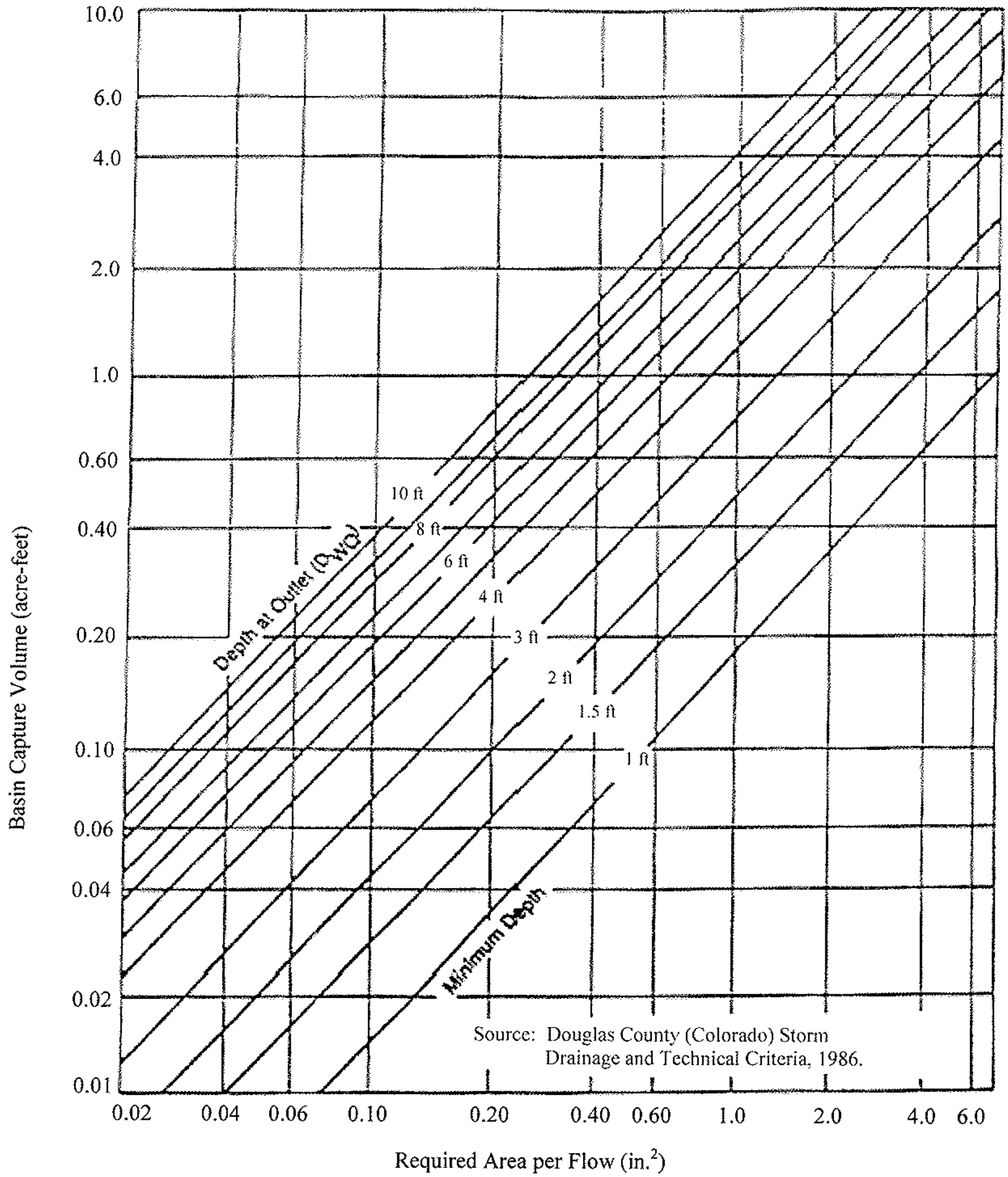
WATER QUALITY
RISER PIPE
NOT TO SCALE

Maximum Number of Perforated Columns

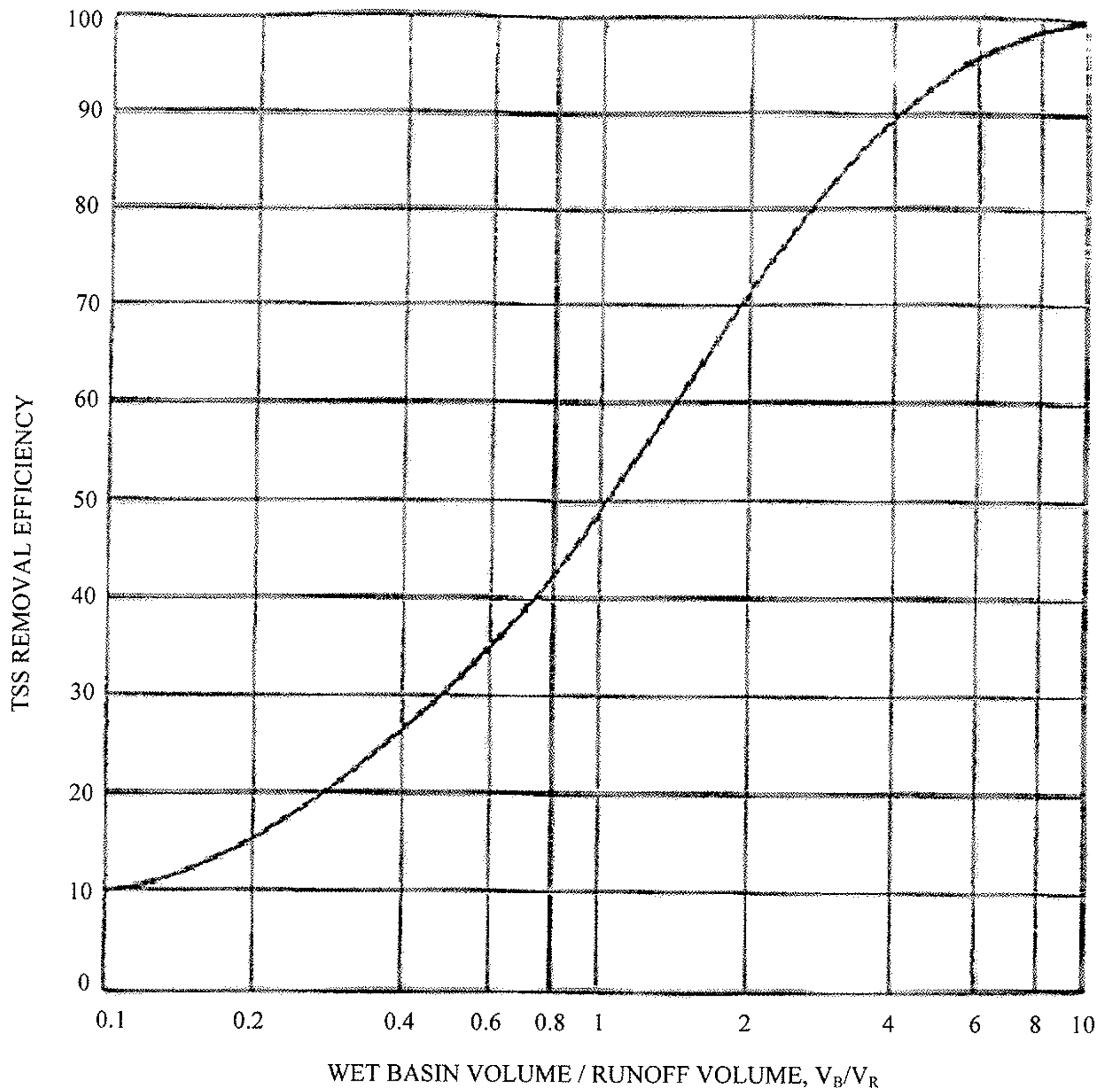
Riser Diameter (in.)	Hole Diameter, inches			
	¼"	½"	¾"	1"
4	8	8	-	-
6	12	12	9	-
8	16	16	12	8
10	20	20	14	10
12	24	24	18	12

Hole Diameter (in.)	Area ($in.^2$)
1/8	0.013
1/4	0.049
3/8	0.110
1/2	0.196
5/8	0.307
3/4	0.442
7/8	0.601
1	0.785

Figure WPTP-01-5
Perforated Riser Pipe Outlet Structure



WPTP-01-6
Water Quality Outlet Sizing: Extended Detention Basin
(40-hour Drain Time of Capture Volume)



Source: FHWA (1989)

Figure WPTP-01-7
TSS Removal Efficiency
Versus V_B/V_R Ratio

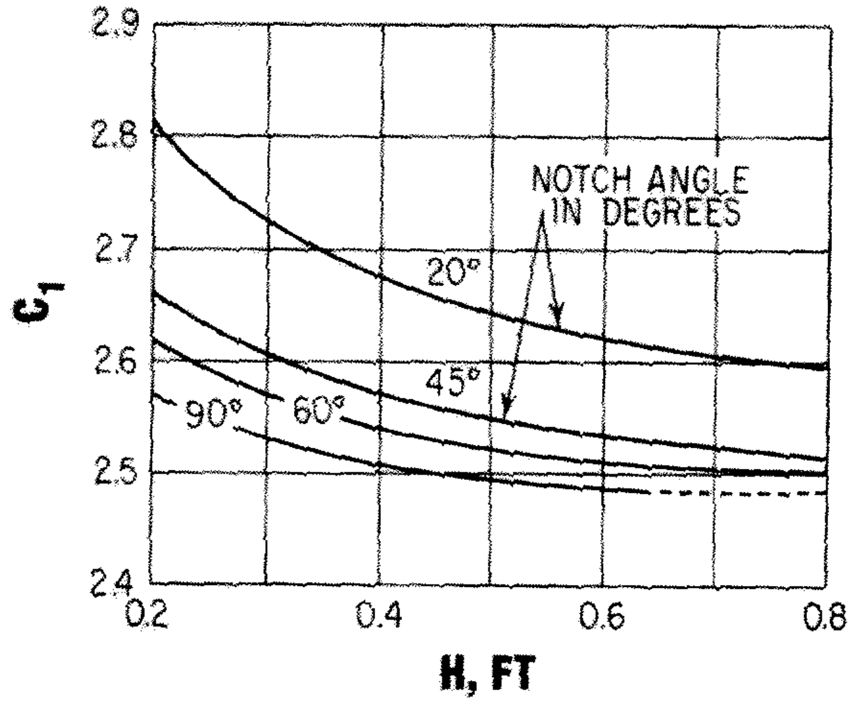


Figure WPTP-01-8
Sharp-Crested "V" Notch Weir Discharge Coefficients

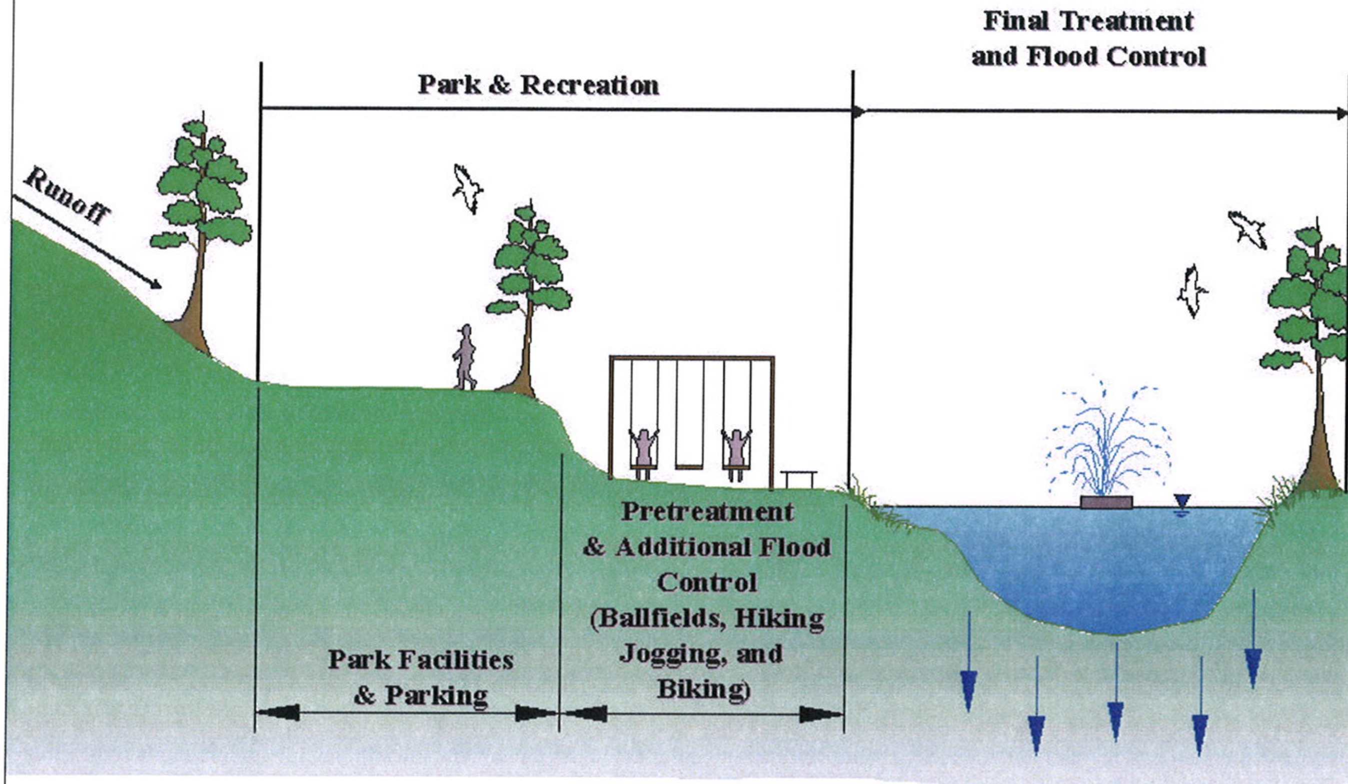


Figure WPTP-01-9
Multi-Use Regional Facility